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13. ABSTRACT *(Maximum 200 words)*

The Secretary of Defense has directed the military services to allow women to fly aircraft engaged in combat missions. The current inventory of naval aircraft was physically designed to accommodate a majority of the male population. Anthropometric standards from 1964 are regularly used for selection, but muscular strength standards for aviation do not exist. This work was done to aid the Navy in safely opening the anthropometric accommodation range for aviation by determining gender-neutral strength requirements for all applicants. The objectives of this study were to: (1) identify strength-critical tasks in naval aircraft, (2) develop data bases on current strength and anthropometric measurements of male and female aviation candidates, (3) develop gender-neutral strength standards to construct an aviation strength screening device, and (4) develop a physical strength enhancement program to assist individuals to meet or exceed the strength standards. Significant differences between male and female aviation candidates in upper or lower body strength and body measurements were found. Upon completion of this work, the strength screening device and aviation physical training program will be delivered to the Commanding Officer, Naval Aviation Schools Command.

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Lloyd B. Meyer PhD 9/3/96

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INTRODUCTION

A recent memorandum from the Assistant Secretary of the Navy stated: "We are faced with a multitude of challenges, as we strive to integrate women into Navy and Marine Corps aircraft. Equipment and cockpit designs are based on male sizing. This severely limits the pool of eligible female pilots. New pipeline training aircraft (Joint Primary Aircraft Training System [JPATS] and T-45) will accommodate a much wider range of eligible females. As our flight experience expands, we are identifying additional female concerns and issues. The following is a list of some of these: safety and survivability; specific physiological and psychological needs; clothing and protective equipment; cockpit fit and compatibility and assignment potential in fleet aircraft. These issues are not Navy and Marine Corps unique but shared by the other services."

The National Academy of Sciences described these issues in the Defense Womens Health Research Program (DWHRP) guidance report. Subsequently, the Bureau of Naval Personnel (BUPERS) requested that the Bureau of Medicine and Surgery (BUMED) address these concerns. As a result, the Naval Aerospace Medical Research Laboratory (NAMRL) was asked to work with the Naval Aviation Schools Command (NASC), Pensacola, FL, to develop a research plan to address these issues. The result was this study that addressed two of the above issues, cockpit compatibility and fleet aircraft assignment.

This research was directly related to the female aviator's ability to safely perform her mission. Insufficient strength can pose problems that may affect the well-being of female aviators and compromise missions. The development of gender-neutral strength standards for naval aviation was a fundamental goal of this study. Methods to efficiently achieve optimal physical fitness, as it pertained to aviation duties, were studied. Because of its strong positive correlation with strength, anthropometric data were also acquired and analyzed. These were new data that may eventually be used in the design and sizing of female aviation clothing and life support equipment. However, the ultimate benefit of this work may be increased aviation safety.

The current Department of Defense (DoD) policy authorizes both male and female pilots and Naval Flight Officers (NFO) to compete for combat aircraft assignments[1]. Some personnel will be restricted from flying certain aircraft because of strength and safety concerns, but, as a result of this research, these restrictions will be based on scientifically-derived standards that will be applied equally to all aviation applicants. Because of the wide range of affected personnel, the results of this study may be used by the U.S. Army, the U.S. Air Force, and many foreign countries that fly American-made aircraft.

Presently, the only physical strength/endurance tests utilized in naval aviation are the Navy's Physical Readiness Test (PRT)[2] and specific physical training activities in the NASC physical training curriculum, i.e., the obstacle course, cross-country course, etc. Even though these programs are gender- and age-normed, they have not been validated against specific aviation occupational strength requirements.

It's known that physical exertion is required for routine and emergency tasks (e.g., high-G maneuvers, manual landing gear extension, ejection seat actuation, manual opening and closing of hatches and canopies) in many naval aircraft. Muscular endurance becomes an important limiting factor when considering multi-engine aircraft requiring large forces on the controls for extended periods of time. Conditions such as hydraulic failure, engine flameout, crosswind landings, and dive recovery can be factors that may cause muscular fatigue. Quantitative values of the strength and endurance required to operate aircraft in certain situations was not commonly known or used as standards. The current physical testing does not predict the success of pilots/NFOs in accomplishing specific aircraft tasks. This creates a serious safety concern as (combat) aviation opens to a wider anthropometric population base.

Previous studies have shown strength differences between men and women especially in upper body muscles[3,4,5,6,7,8,9]. In a review of literature, Laubach reported that women were found to range from 35 to 79% of men's upper extremity strength, averaging 55.8%[10]. Teves, et al, found, when normalized for body weight, females were 75% as strong as males on isometric measurements[11]. Robertson reported the greatest strength differences between men and women on upper torso dynamic strength tests, push-up, pull-up, and bent arm hang, where women's means were 10, 5, and 23 percent of men respectively[12]. Most of these studies concluded that the strength differences were due to smaller muscle mass in women.

Muscle mass differences have been observed in smaller stature men as well as women. McDaniel also found that men were stronger than women when measured on 10 different aircraft tasks[13]. However, his study concluded that the correlation between strength and size was low and that cockpit designers and evaluators should not select test subjects based solely on their strength characteristics. Whether the issue is strength dependent on size or independent of size, all of the previous studies have suggested a need for task-specific, gender-neutral strength testing for aviation.

However, there has been a lack of research in the area of human interaction (gross motor involvement) with the aircraft. Without documentation of the actual movements and muscle electrical activity performed by an aviator within the cockpit, research on the effects of strength and anthropometric variables have little relevance. Motion analysis of ejection seat mechanics has shown that anthropometry may have as great an effect on performance as strength[12]. Therefore, in this study, motion analysis of the required movements during aviation occupational tasks was done to corroborate the muscle identification and assist in the development of the strength screening device. This aspect of the work on the movements of aviators within the cockpit was done to facilitate a greater understanding of the interaction between human and machine.

BODY

METHODS

The research was conducted in three phases. Phase I began in FY95 and was completed in FY96. Phases II and III began in FY96 and will be completed in FY97. In Phase I, critical naval aviation occupational performance tasks (in cockpit) and their associated force requirements were identified and evaluated. Additionally, actual strength and anthropometric data were gathered on male and female aviation candidates to be used in the development of screening standards. In Phase II, the results of Phase I were used for the construction of the aviation strength screening device. A remedial physical conditioning program was developed specifically for aviators deficient in strength. In Phase III, the strength screening device and remedial strength training program will be validated. The remedial physical conditioning program was designed to enable candidate pilots and NFOs to meet or exceed the requirements of the strength screening device. A final report will be prepared and distributed completing Phase III. Recommendations for follow-on studies and the transfer of the screening device and training program to NASC will be made at that time.

Occupational Tasks and Strength Requirements

Initially, an extensive review of pertinent military, sports medicine, and human factors literature was accomplished to determine the extent of previous efforts in this area. Because of the time since prior studies, it was deemed that a new analysis of aircraft occupational tasks was necessary. Initially, performance-based strength requirements for manual tasks accomplished in flying were solicited from experts on every aircraft in the Navy's inventory. Experienced naval aviators who have a high number of flying hours in specific aircraft are designated by the Navy as "aircraft model managers." Each model manager was asked to analyze their respective aircraft for the critical tasks that challenged the strength of the pilot and were essential to the operation of the aircraft under normal and extraordinary situations. They were requested to recall from their experiences the control surfaces that required manual manipulation that was difficult to perform and the forces correlating with those movements. As a result, the assessment identified the most important aircraft actions that required strength and endurance.

Some of the force data was derived from engineering information on each aircraft by contractors and engineers from the Naval Air Warfare Center-Aircraft Division (NAWCAD), Patuxent River, MD. Additional force data were obtained through liaison with aircraft contractors, Fleet Replacement Squadrons' simulator activities, and Navy aircraft engineers. From all of these eforts, a comprehensive list of potentially forceful movements was complied, and the tasks common to most aircraft, or that were extremely important to the operation of an aircraft, were identified as the occupational tasks that would be incorporated in the strength screening device.

NAWCAD was also contracted by NAMRL to measure all naval aircraft to obtain the upper body and lower extremity forces needed to perform the aviation occupational tasks that had been identified. A FARO-Arm™ portable three-dimensional measuring machine was used to assist and expedite the completion of gathering missing force data. It was used to map the cockpits of all naval aircraft. The resulting strength requirements in pounds of force for selected movements of the stick, wheel, rudder, collective, and other controls were compiled and eventually used in the development of the strength screening device. These force data for each aircraft are summarized in Appendix E.

Motion Analysis

Motion analysis was done to validate the performance of the occupational tasks that had been identified. Two video cameras were placed at appropriate positions to capture different views of the critical tasks involved within the cockpit. The tasks were identified as: (1) ejection seat actuation; (2) stick and rudder pedal movement of the T-34C; (3) manual landing gear cranking in the T-34C aircraft; (4) cyclic, tail rotor pedal, and collective movements within a helicopter (TH-57); and (5) wheel and yoke movement in the C-130 aircraft. A control object was placed in the cockpit prior to filming as a reference for the conversion of the coordinate values to video images.

After data collection, the 2-dimensional video images were captured from each video view, specific body landmarks were digitized, and the video images with the control object were transformed with the Direct Linear Transformation algorithm[14]. The raw three-dimensional data points were smoothed with a Butterworth digital filter set at 6 Hz. All data analysis was done with the Ariel Performance Analysis System. Linear and angular displacements, velocities, joint forces, and moments were determined for specific joints of the body related to each task[15,16].

Linear displacements in the X (horizontal), Y (vertical), and Z (lateral) directions were determined after plotting the digitized points of the joint coordinates[17]. Joint angular displacement was plotted between one segment relative to another about the joint shared in common. The motion was reported in the polar coordinate system as a relative angular component about the pole (joint) as viewed along the XY, XZ, YZ planes. The magnitude of the X, Y, Z joint reaction forces was calculated from the kinematics with reference to the Cartesian reference coordinate system selected by the control points. The joint reaction forces in the X, Y, and Z directions were determined from a link-segment model. Net muscle moments, acting at each segment, were determined from the angular acceleration, reaction forces, and moment of inertia values obtained using the link-segment model[18].

Strength and Anthropometric Data

The strength and anthropometric data collected in Phase I were used as criterion standards representative of the current aviation candidate population to compare to the forces built into the screening device. An anthropometer and state-of-the-art strength measuring device (Cybex 6000) were used to measure body sizes and muscular strength. Student naval aviators, student NFOs, and First and Second Class Midshipmen from the U.S. Naval Academy were tested on a strength and endurance battery and anthropometric measurement series. Both male and female subjects were tested. Power calculations indicated that 150 female subjects were needed for valid comparisons with male subjects. We tested 610 subjects overall, 458 males and 152 females. Muscular strength and endurance were measured with the Cybex 6000 Muscle Testing Device. Three major muscle groups were selected for testing because of their involvement in performing most of the critical occupational tasks in aviation requiring muscular control. Using the Cybex, the muscle groups that were tested were: the large muscles of the upper leg that extend and flex the knee (quadriceps and hamstrings), the muscles acting on the shoulder joint to cause rotation, and the elbow extensors and flexors (biceps and triceps).

The Cybex was configured to measure isokinetic concentric muscular forces for both flexion and extension. Isokinetic resistance exercise employs a fixed speed of movement with a variable resistance accommodating to the individual throughout the range of motion. For strength, the speed of movement was set at 60°/sec, and 3-4 maximal exertion repetitions were performed. Following each strength set and a short rest period, a set of 20 maximal exertion repetitions at 180-240°/sec were done for endurance. Only the right side of the body was tested to reduce the time of participation and maintain uniformity. Strength and endurance variables measured included: peak torque, torque acceleration energy, average power, and total work. Definitions of the strength variables are listed in Appendix B.

Grip strength in both hands was measured with a hand grip dynamometer. The best of three trials was recorded. All of the subjects were given verbal encouragement by the operators during the strength and endurance tests.

Skinfold measurements and fifteen body dimensions were included in the anthropometric analysis. The sum of three skinfolds was used to determine body composition and to estimate body fat[19]. Skinfold measurements for males were taken at the chest, abdomen, and the thigh. Females skinfold sites were the triceps, the suprailiac, and thigh. Results of the skinfold measurement were used to better assess strength by relating the anthropometric variables to lean body mass.

For anthropometry, body weight and fourteen different body measurements of stature and limb length were chosen because of their importance to proper cockpit fit. The specific anthropometric variables measured were: weight, stature, thumbtip reach, bideltoid breadth, sitting height, sitting eye height, sitting acromial height, abdominal extension depth, sitting hip breadth, thigh circumference, thigh clearance, buttock-knee length, sitting knee height, and functional leg length. An anthropometer was used following the methods described by Gordon, et al[20]. Three measurements were made on each dimension with the average of the three used for analysis. The anthropometric variables listed above are defined in Appendix C.

Descriptive statistics were determined on all variables. Means and standard deviations for strength and endurance data as well as the anthropometric data were determined. Student's t-tests were performed for comparison of male and female data. The anthropometric data for both gender groups and the total sample data were analyzed for differences. Statistical significance was set at $P < 0.05$. Correlational analysis was done to determine collinearity, or the amount of variance accounted for by each variable, in the model. Percentages of female-to-male comparisons of strength variables were also calculated. To validate the strength test battery, the remedial conditioning program, and the aviation strength training program, discriminant analysis will be used to identify the most important variables for each of the tests. Multiple regression analysis will be employed to develop regression equations for predicting aviation occupational task performance on the screening device from strength assessment.

Cockpit Strength Screening Device

The strength screening device was designed like a generic cockpit simulator that was programmed to measure the performance of aviators on selected manual aviation tasks. It was built to screen candidate pilots and NFOs to determine whether they can meet the minimum strength requirements to perform the designated tasks in all naval aircraft. The strength screening device was constructed under contract at the Ergonomics Laboratory, Wright-Patterson Air Force Base, Ohio. The cogent analyses done by the

Model Managers coupled with the strength requirements compiled by the Naval Air Systems Command (NAVAIRSYSCOM) representatives and contractors at NAWCAD were used to ensure that the cockpit simulator had realistic forces on the control surfaces. It was built to be easily configured to simulate different aircraft and to provide a generic "cockpit-like" environment capable of evaluating all aviation candidates within Navy anthropometric standards.

One of the control forces was the center stick movement of the ailerons and elevator. The design of the device was such that forces can be measured in both the forward/aft and right/left planes. Each force can be measured through a range of motion characteristic of the F/A-18 stick with the maximum force measured at the end of the range of motion. In addition to a maximum force measurement, an endurance test was included in which the candidate will be required to maintain a specific force on the control surface for a preset length of time. An electronic monitor provides the necessary feedback so that the candidate will know how much force is needed and the time remaining in the test.

The device was constructed such that the stick hardware can be reconfigured to represent a P-3 wheel and yoke. The reconfiguration does not require the use of any tools and can be accomplished within 2 minutes by one person. When in the wheel and yoke set-up, the range of motion in both the forward/aft and the right/left rotation is the same as that found in the P-3 aircraft. Both short-term maximal and endurance forces can be measured with the wheel in any combination of aileron/elevator (with the wheel anywhere in the forward/aft plane while simultaneously measuring the force rotating the wheel either right or left).

Since this device will be used to screen aviation candidates for both fixed wing and helicopter, a collective was integrated into the design. The collective was modeled after the UH-60 with the placement relative to the seat and the range of movement similar to that found in the UH-60. The forces evaluated with the collective are the raising and lowering of the collective.

Another control surface force evaluated in the device is the movement of the rudder pedals. The pedals will be located and function like those found in the F/A-18. Like the stick and the wheel, there will be not only a maximal force measured, but also an endurance test available.

The ejection seat handle pull was another critical task identified. The device incorporates both the lower and the upper (face curtain) ejection seat handles. Although the seat resembles an F/A-18 seat that does not have a face curtain handle, modifications have been made to include one since other ejection seat aircraft possess them. The lower ejection seat handle pull requires both a "break out" force to dislodge the handle from the holder and additional effort representing the movement to actuate the ejection seat. The force measurement is the maximum force exerted after the breakout force and measured over the range of motion similar to that found in the F/A-18 aircraft. The upper ejection seat pull is static (isometric) with only the maximum force measured.

The T-34C is the one aircraft flown by all naval aviators during training. One of the tasks required for completion of the initial phase of flight training is the manual lowering of the landing gear. This aircraft has a small hand crank located on the right side of the cockpit which must be turned approximately 42 turns to fully lower the landing gear. The force required to turn the crank increases with the number of turns. The screening device incorporates a mockup of the landing gear crank capable of measuring the force exerted while turning the handle against a resistance similar to that felt in the aircraft. When tested, the subjects will be restrained as they would be in a cockpit to effect realistic muscular movements.

Computer hardware and software requirements for the strength screening device included:

(1) A calibration check of the simulator.
(2) Test setup interface for examiner (for each desired test scenario).
(3) Capability to prompt the examiner for each correct setup of the system (i.e., control selection, seat and pedal position).
(4) Verification of correct setup before proceeding.
(5) Instructions and feedback to subjects during test.
(6) Collection of data during test.
(7) Quality control tests on data.
(8) Computation and storage of test results.

In the third phase of the project, the screening device will be validated by testing designated aviators from different aircraft on the various tasks to evaluate the force characteristics. The device will be housed in the NAMRL Mobile Field Laboratory (MFL) along with the Cybex strength measuring device, allowing for successive force measurements of a specific task on both the screening device and the Cybex.

Initially, the screening device will be used to gather baseline strength data. During this period, flexibility in test selection, setup, and data analysis is required. After the screening device has been fully evaluated, only a few test scenarios will be necessary for evaluation of aviation candidates. The computer controlling the device will have the capability to compare each subject's test results with the requirements for all naval aircraft.

The data on all Navy aircraft cockpit characteristics as well as all of the subjects' data will be stored on the computer to compare the test results with aircraft characteristics. The subject data will be archived for population statistical analysis. The data spreadsheet will be compatible with Lotus 123. Specific details on the construction of the screening device will be published in a future technical report.

Remedial Physical Conditioning Program

In Phase II, a remedial physical conditioning program was developed for NASC candidates selected for naval aviation. The program was designed specifically to improve strength in muscle groups used in accomplishing the critical manual tasks involved in flying naval aircraft. The program incorporated the physical training policies and equipment already in place at NASC. The remedial program consisted of a series of exercises selected to enhance the functional capability of particular muscle groups to better perform aviation-related occupational tasks similar to those employed in the strength screening device.

The most important occupational tasks requiring muscular exertion and their specific maximal forces were identified in Phase I. Likewise, a study of the movements of these tasks reaffirmed the identification of the anatomical parts of the body involved with each movement. From the motion analysis and force determination information, the best exercise routine to enhance the strength and endurance of those muscles was designed (Appendix F). In Phase III, extensive testing will be done to validate the program. The remedial physical conditioning program is flexible and includes both calisthenics and exercises that can be performed with strength training equipment usually found at naval bases or onboard ships. Specifics into the correct performance of each exercise including the frequency, duration, and intensity are detailed in the program. When followed correctly, aviators found deficient in strength in any area identified by the screening device will be able to improve their strength and endurance within a reasonable period of time and maintain a level of muscular proficiency throughout their career. The benefits from such a program include increased inflight safety, enhanced aviation task performance critical to mission accomplishment, elevated confidence, and improved health.

RESULTS AND DISCUSSION

The results of the strength and anthropometric measurements made on 610 male and female aviation candidates are shown in the tables in Appendix G. Tables 1 and 2 compare the means of muscular strength and endurance variables. In all of the measurements, strength and endurance of the males were significantly greater than those of the female subjects. Percentage comparisons of female to male strength and endurance measurements are shown in Table 10. The strength in the large muscles of the upper leg, quadriceps and hamstrings, of the female candidates was 60 to 67% of the strength and endurance of the males respectively. Elbow and shoulder strength and endurance was less (45 to 65%) than that of the males, as would be expected. However, most all of the female measurements were in the upper half of the measurement ranges of other studies of comparable populations. Whether the strength and endurance attributes of female aviation candidates are adequate to operate all of the aircraft in the naval inventory cannot be determined at this point.

The anthropometric data in Table 3 show that male aviation candidates were significantly greater in all of the body dimensions that were measured than their female counterparts except for hip breadth and thigh circumference. These data were representative of other anthropometric studies of males compared to females. However, this is new information that should prove beneficial to aircraft cockpit designers and manufacturers of aviation life support equipment since there are no other current anthropometric studies on female aviators. The other anthropometric factor that showed a significant difference between males and females was body composition ($t=-21.84$, $df=258.47$). Women were found to have a greater percentage of body fat (22.5 vs 13.3%) when compared to their male counterparts.

The correlations of anthropometric and strength data for males and females are shown in Tables 4 through 9. Knee, shoulder, and elbow strength and endurance variables were correlated with the anthropometric measurements for each group. In all cases, there were direct positive correlations between variables. Although the strength of the correlations was not exceptional, considerable collinearity existed between the anthropometric and strength variables for both groups.

Aviation tasks are complex and multi-faceted. An analysis of the occupational tasks involved with flying may overlap between different aircraft types, but there remains some functions that are unique to a particular aircraft. Several critical tasks in naval aircraft requiring muscular strength and endurance have been identified. These tasks were used to develop a strength screening device that resembles a generic aircraft cockpit and can be configured like a jet, multi-engine propeller, or rotary wing aircraft. As a result, a determination will be made on the competency of females and smaller stature males to physically control any aircraft under any situation.

The criteria for muscular performance for aviation tasks included instantaneous strength, sustained strength, and endurance for routine, emergency, and survival situations in all naval aircraft. Subsequent to the development of standards, a physical conditioning program that will assist candidate pilots and NFOs to meet or exceed the minimum requirements was designed and will be validated. The motion analysis was included to validate the specific movements that were critical to the completion of the tasks within the cockpit.

Since the project has not been completed at the time of this report, only one of the three anticipated products has been completed, that is, the cataloging of strength requirements for all naval aircraft. The other products, the strength screening device and remedial strength training program, have been developed but not validated. The list of strength requirements will be given to NASC and BUPERS. The screening device and remedial strength training program will also be transitioned to NASC upon completion of the validation process.

CONCLUSIONS

The purpose of this work was to develop gender-neutral occupational strength standards for naval aviators.

1. Aviation-related occupational tasks for all naval aircraft were identified. The forces required to complete particularly important tasks were determined.

2. The anthropometric and muscular strength and endurance data from 610 subjects in this study were consistent with the findings of other studies.

3. Female aviation candidates were smaller in all body dimensions than their male counterparts except for thigh circumference, hip breadth, and body fat estimation.

4. Female candidates were weaker in all muscular strength and endurance measurements and exhibited scores in the middle to upper ranges of other studies.

5. The strength screening device was constructed and will be validated in FY97.

6. The aviation strength enhancement program was developed and will be validated in FY97.

7. Gender-neutral occupational strength standards for naval aviation will be delivered to NASC in FY97.

FUTURE CONCERNS

This program succeeded due to DWHRP funding and support during the initial and middle phases. Additional funding was procured through the Department of the Navy to complete the final phase of this project in FY97. During that time, the aviation strength screening device and the strength and endurance training program will be validated. Following the completion of the validation of the device and the training program, both will be transitioned to NASC for implementation. Considering the discrepancies that seem to exist between flight clothing and the body dimensions of current aviation candidates, a future effort to create new anthropometric standards for naval aviation, and from them redesigned flight clothing, should be given future attention and funding.

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APPENDIX A

ACRONYMS AND SYMBOLS

Aircraft Model Manager - Naval aviation activity (squadron) with representatives who are responsible for a specific aircraft platform.

BUMED - Bureau of Medicine and Surgery, Washington, DC

BUPERS - Bureau of Naval Personnel, Washington, DC

C-130 - multi-engine fixed wing (prop) aircraft used for cargo/personnel transport in the Navy.

Center-pull ejection handle - lower handle for actuating emergency escape system (ejection seat) in a tactical jet aircraft.

Cockpit strength screening device - a simulator under construction at Wright-Patterson Air Force Base's Ergonomics Laboratory, which can duplicate actual forces on specific control surfaces..

Collective - control for adjusting engine speed and the vertical direction of a helicopter.

CNATRA - Chief of Naval Air Training, Corpus Christi, TX

CNET - Chief of Naval Education and Training, Pensacola, FL

CNO - Chief of Naval Operations, Washington, DC

CT - criterion tasks or critical tasks identified by aircraft model managers

Cybex - a strength measuring/rehabilitative device manufactured by the Cybex company, and used to measure muscular strength and endurance in this study.

DoD - Department of Defense, Washington, DC

DWHRP - Defense Women's Health Research Program

Ejection seat - a seat with rockets in specific fixed-wing aircraft that jettisons the individual out of an aircraft.

Emergency landing gear crank - unique manually-operated device for lowering the landing gear in a T-34C Navy training aircraft

Face-curtain ejection handle - upper handle (above the head) on an ejection seat which actuates emergency escape system in tactical jet aircraft

G-maneuver - a maneuver performed in tactical jet aircraft which exposes the aircrew to high G forces in one or more axes (X, Y, or Z axes).

JPATS - Joint Primary Aircraft Trainer System, a new aircraft which will be used for initial flight training in all of the military services.

LS-1 - a specific type of ejection seat for a Navy jet aircraft

METROCOM - a portable three-dimensional measuring device (computer-based) for determining distances in the X, Y, and Z planes from a central reference point.

Mobile Field Laboratory (MFL) - a semi-trailer housing test equipment and apparatus, and it can be relocated to other sites for subject testing.

MSG - abbreviation for a naval message which is electronically transmitted to naval activities

NACES - Navy Aircrew Common Ejection Seat, an ejection seat for several Navy jet aircraft.

NAMRL - Naval Aerospace Medical Research Laboratory, Pensacola, FL

NASC - Naval Aviation Schools Command, Pensacola, Fl

NAVAIRSYSCOM - Naval Air Systems Command, Arlington, VA

NAWCAD, Patuxent River - Naval Air Warfare Center - Aircraft Division, Patuxent River. A Navy Research, Test, Development, and Evaluation facility for aircraft in Lexington Park, MD

NFO - Naval Flight Officer

NROTC - Naval Reserve Officer Training Centers at universities

OCS - Officer Candidate School program at Naval Air Station Pensacola for university graduates who did not attend a service academy or the NROTC program at an university

OPNAVINST - Chief of Naval Operations instruction which provides guidance on a topic/issue relevant to Department of the Navy personnel or programs

PRT - The Navy's Physical Readiness Test consists of the Sit-Reach test (touch toes in seated position), the Push-up test (number of push-ups in 2 minutes),the Sit-Up test (number of sit-ups in 2 minutes), 1.5 mile run/walk, and the 500 yard swim (optional for run). The PRT is discussed in the Navy's Physical Readiness instruction, OPNAVINST 6110.

Rudder Pedals - control surface to actuate the aircraft's rudder and change the aircraft's movement in the yaw axis

Stick aileron/elevator - control surface for pitch and roll axes of the aircraft.

T-2 - A fixed-wing jet aircraft trainer in the Navy

T-34 - A fixed-wing propeller-driven aircraft trainer in the Navy

TH-57 - A rotary-wing aircraft (helicopter) used for primary helicopter and advanced helicopter training in the Navy.

USAF - United States Air Force

Wheel aileron/elevator - control surface for pitch and roll axes of the aircraft

APPENDIX B

STRENGTH DEFINITIONS

Average Power - the total work divided by the time it takes to perform the work.

Peak Torque - the greatest torque generated by a muscle contracting through a range of motion.

Torque Acceleration Energy - the total work in the first 1/8 of a second of a contraction through a range of motion.

Total Work - the total work performed in all repetitions of each set.

APPENDIX C

ANTHROPOMETRIC DEFINITIONS

Abdominal Extension Depth - the greatest horizontal distance between the anterior point of the abdomen and the back at the same level in the anthropometric sitting position.

Acromial Height, Sitting - the vertical distance between the sitting surface and the tip of the shoulder in the anthropometric sitting position.

Bideltoid Breadth - the greatest horizontal distance between the outside edges of the deltoid muscles on the upper arms in the anthropometric sitting position.

Buttock-Knee Length - the horizontal distance between the back of the buttock and the front of the knee in the anthropometric sitting position.

Eye Height, Sitting - the vertical distance between the sitting surface and the outer corner of the eye in the anthropometric sitting position.

Functional Leg Length - with the leg fully extended, the straight-line distance between the footrest surface and the back surface of the body in line with the tip of the trochanter.

Height, Sitting - the vertical distance between the sitting surface and the top of the head.

Hip Breadth, Sitting - the most lateral points on the hips or thighs, whichever are greater.

Knee Height, Sitting - the vertical distance between the footrest surface and the top of the knee in the anthropometric sitting position.

Stature - the vertical distance between the standing surface and the top of the head.

Thigh Circumference - circumference of the thigh at its juncture with the buttock perpendicular to thigh's long axis.

Thigh Clearance - the vertical distance between the sitting surface and the highest point on the top of the thigh.

Thumbtip Reach - standing with shoulders against a wall, the horizontal distance between the back wall and the tip of the thumb when the arm is stretched forward horizontally.

APPENDIX D

STATEMENT OF WORK

This proposal outlines a research study originally designed to be completed over a four year period. The goal of the project was to provide a scientifically-derived means for identifying aviation candidates not possessing adequate strength to safely operate naval aircraft. This study was started and accelerated with DWHRP funds in FY95. The project is 75% complete. DWHRP continuation funds to complete the project in FY97 were not granted. However, funding from the Department of the Navy has been identified that will allow the completion of the project in FY97.

The following statement of work was originally submitted with the initial proposal:

The project was designed in 3 phases. Completion of Phase I will deliver a strength screening device. Completion of Phase II will deliver a pre-screening protocol to be used to predict success on screening device and prevent unnecessary money lost from personnel transfers. Completion of Phase III will deliver a remedial physical training protocol to assist individuals not initially able to meet screening standards.

Pending receipt of funds, the following milestones will be met (completion milestones are in parentheses). A background literature review was completed and published (Feb, 95). Experts on each naval aircraft were surveyed to determine strength critical tasks for each aircraft (Nov, 94). Force data were derived for each task to determine force requirements for the screening device design (Jul, 95). Motion analysis of each task was done to assist with all project phases (Jan, 96). All critical task, force, and motion analysis data were provided to a sub-contractor to assist in the design and construction of the screening device (Jan, 96). A strength/anthropometry data base was established by testing 663 aviation candidates (Aug, 95). These data will be used in Phases II and III. The screening device will be validated using 150 male and female pilots and aviation candidates to assure device measurements are accurate (Jun, 96). The pre-screening protocol will be designed and validated with the screening device (Sep, 96). The remedial physical training program will be designed to specifically strengthen muscle groups used for each critical task. Any individual not able initially to pass the screening will be directed to strengthen associated muscles with this program (Sep, 96). The last project milestone is to complete a final report on the overall project (Dec, 96).

APPENDIX E

SCREENING DEVICE FORCE DATA REQUIREMENTS
(FORCES AT THE END OF THE RANGE OF MOTION)

STICK FORCES	
<u>Longitudinal</u>	
Forward (Push)	27 lbs
Back (Pull)	32 lbs
<u>Lateral</u>	
Left	31 lbs
Right	31 lbs
WHEEL FORCES	
<u>Longitudinal</u>	
Forward (Push)	80 lbs
Back (Pull)	108 lbs
<u>Lateral</u>	
Left	55 lbs
Right	55 lbs
RUDDER PEDAL FORCES	
Left	200 lbs
Right	200 lbs
COLLECTIVE FORCES	
Raise	26 lbs
Lower	45 lbs
EJECTION SEAT FORCES	
Lower	40 lbs
Upper	55 lbs

APPENDIX F

NAVAL AVIATION STRENGTH AND ENDURANCE CONDITIONING PROGRAM

The purpose of the Naval Aviation Strength and Endurance Program (NASEP) is to enable aviation candidates and designated aviators to sufficiently perform manual procedures to control of naval aircraft during any circumstance. This unique physical training program specifically affects all of the musculature used in flight control. It was based on the results of current scientific research in strength training. When this program is followed strictly, significant gains in strength and endurance will be seen in a minimum of six weeks. When used as a remedial conditioning tool, this program will enhance the muscular strength and endurance to permit aviation candidates to successfully complete the maneuvers on the NAMRL/NASC Naval Aviation Strength Screening Device (NASSD). Additionally, this training program may be used as the basis for a general conditioning program or as a maintenance strength training program for designated aviators along with any other type of physical conditioning plan.

The key to success with this program is to use it precisely as it was designed. The frequency, intensity, and schedule of exercises with their appropriate rest periods must be followed as given. If personal deviations are made in the program, adequate, timely results may not be acquired. The exercises must be performed exactly as instructed. Improvements in strength and endurance depend on personal dedication and compliance with the program. Remember, the program was designed to enhance the strength and endurance of muscles, regardless of gender, used to fly naval aircraft. If implemented properly, it can benefit the aviator from a mental as well as a physical standpoint.

The Aviation Strength and Endurance Program was designed by Dr. Scott Meyer at NAMRL. He designed the G-tolerance Enhancement Strength and Endurance Training Program eleven years ago that was adopted by the U.S. Air Force and was published as a Navy technical report. Specific questions regarding the program, may be directed to Dr. Meyer at (904)452-2556 or DSN 922-2556.

The NASEP listed below includes the schedule of workouts, the individual exercises, the sequence of performance, rest periods, and the manner of performing each exercise. The program was designed to maximize results in a minimum amount of time. When used as a remedial program to overcome deficiencies noted on the NASSD, only the exercise(s) indicated for the muscles of a particular movement may be employed. However, if the deficiency is in the limbs, it is important that both limbs are involved in the training even though only one of them may be deficient in actuating the control on the NASSD.

NAVAL AVIATION STRENGTH AND ENDURANCE CONDITIONING PROGRAM

There are two distinct components to this program. One enhances <u>muscular strength</u>; the other builds <u>muscular endurance</u>. Follow this schedule as outlined. If it cannot be performed as listed, contact one of the trainers conducting the program or Dr. Meyer at NAMRL. The trainers will be available during workout sessions to ensure the exercises are properly executed to complete the program successfully. It is important to warmup properly before each session. When more repetitions can be done than are indicated, raise the weight. If you incur an injury, notify your trainer or Dr. Meyer.

<u>Program</u>: Resistance training program using isotonic equipment, i.e., Universal Gym, Nautilus, free weights, to enhance both strength and endurance.

<u>Length of Program</u>: 6 weeks

<u>Strength Workout</u> - 1 hour

Frequency: Monday, Thursday

Warmup: 5-10 minutes of stretching before and after session

Performance: Control weights throughout exercise, 3-6 seconds for positive (concentric) and negative (eccentric) contractions

Rest periods: 2 minutes between sets

Exercise	Sets	Repetitions/Intensity
1. Leg Press or Squats	5	6 @ 6 RM*
2. Seated or Bent-over Rowing	4	6 @ 6 RM
3. Bench Press	4	6 @ 6 RM
4. Lat Pull	3	6 @ 6 RM
5. Triceps Extension (seated, supine, or standing)	3	8 @ 8 RM
6. Arm Curl	3	6 @ 6 RM

* RM = Repetition Maximum level of intensity, the amount of weight that can be lifted for only that specified number of repetitions with good form.

Endurance Workout - 30 minutes

Frequency: Tuesday, Friday

Warmup: 5-10 minutes of stretching before and after session

Performance: Control weights throughout exercise, 3-6 seconds for positive (concentric) and negative (eccentric) contractions

Rest Periods: 30 seconds between sets, 60 seconds between exercises

Exercise	Sets	Repetitions/Intensity
1. Leg Press or Squats	6	15 @ 15 RM
2. Bench Press/ Upright Row	3**	10 @ 10 RM
3. Seated Row/ Lat Pull	3**	10 @ 10 RM
4. Triceps extension/ Arm Curl	3**	10 @ 10 RM

** Exercises performed as "super sets"; when a set of an exercise is completed, immediately perform the second exercise before resting, i.e., 10 bench presses followed immediately by 10 upright rows. This is done 3 times.

APPENDIX G

DATA TABLES

Table 1. Means (X) and Standard Deviations (SD) of Muscular Strength Variables of Male and Female Aviation Candidates

Variables	Male (n=458) X	Male (n=458) SD	Female (n=152) X	Female (n=152) SD	t-value
Knee					
Flexion					
Peak Torque (ft-lbs)	99.62	17.84	64.06	11.94	22.19*
TAE (ft-lbs)	7.52	1.79	4.71	1.11	18.17*
Extension					
Peak Torque (ft-lbs)	172.12	30.47	113.20	20.47	22.23*
TAE (ft-lbs)	11.68	2.62	7.05	1.52	20.67*
Elbow					
Flexion					
Peak Torque (ft-lbs)	41.01	7.82	22.78	4.89	27.38*
TAE (ft-lbs)	2.48	0.85	1.12	0.42	19.20*
Extension					
Peak Torque (ft-lbs)	44.34	9.34	28.74	6.42	19.30*
TAE (ft-lbs)	3.61	0.77	2.11	0.44	23.03*
Shoulder					
Flexion					
Peak Torque (ft-lbs)	26.09	5.87	15.94	3.90	20.13*
TAE (ft-lbs)	2.65	0.63	1.48	0.41	21.86*
Extension					
Peak Torque (ft-lbs)	42.75	9.01	25.81	5.45	22.13*
TAE (ft-lbs)	3.79	0.97	2.18	0.59	19.58*
Grip Strength					
Right (kg)	52.01	6.96	36.39	5.19	11.63*
Left (kg)	49.57	6.87	34.01	5.13	11.32*

* $P < .05$
TAE = Torque Acceleration Energy
Variable are defined in Appendix B.

Table 2. Means (X) and Standard Deviations (SD) of Muscular Endurance Variables of Male and Female Aviation Candidates

Variables	Male (n=458)		Female (n=152)		t-value
	X	SD	X	SD	
Knee					
Flexion					
Total Work (ft-lbs)	80.79	16.31	52.82	12.11	19.44*
Ave Power (W)	203.13	41.06	136.06	29.47	18.61*
Extension					
Total Work (ft-lbs)	123.11	23.02	78.03	16.32	22.35*
Ave Power (W)	303.09	64.94	196.13	41.41	19.06*
Elbow					
Flexion					
Total Work (ft-lbs)	38.35	9.56	17.14	5.60	26.22*
Ave Power (W)	90.19	24.18	38.76	13.49	25.25*
Extension					
Total Work (ft-lbs)	47.13	9.46	25.88	6.33	25.14*
Ave Power (W)	109.41	23.76	61.10	15.44	23.75*
Shoulder					
Flexion					
Total Work (ft-lbs)	25.32	6.69	13.86	4.43	19.95*
Ave Power (W)	53.93	14.86	30.81	10.01	18.08*
Extension					
Total Work (ft-lbs)	48.19	9.79	28.48	6.33	23.51*
Ave Power (W)	101.19	23.24	62.89	14.73	19.30*

* $P < .05$
Variables are defined in Appendix B.

Table 3. Means (X) and Standard Deviations (SD) of Anthropometric Variables of Naval Aviation Candidates

Variables	Male (n=458)		Female (n=152)		X Difference t-value	Total (n=610)	
	X	SD	X	SD		X	SD
Weight	79.33	9.52	64.60	8.27	18.18*	75.71	11.19
Stature	179.37	6.62	167.01	6.09	21.21*	176.29	8.41
Thumbtip Reach	82.63	4.35	75.11	3.86	17.40*	79.93	5.52
Bideltoid Breadth	49.55	2.70	44.97	2.39	19.77*	48.41	3.29
Abdominal Extension Depth	22.87	2.09	20.17	2.05	14.00*	22.19	2.39
Hip Breadth, Sitting	36.15	2.36	38.01	2.69	-7.61*	36.61	2.57
Height, Sitting	93.13	3.39	87.73	2.99	18.63*	91.78	4.04
Eye Height, Sitting	80.98	3.09	76.02	2.95	17.74*	79.74	3.73
Acromial Height, Sitting	60.75	2.95	57.47	2.76	12.50*	59.93	3.23
Thigh Circumference	59.76	4.31	59.15	4.09	1.55	59.61	4.26
Thigh Clearance	17.32	1.18	15.98	1.13	12.45*	16.99	1.30
Buttock-Knee Length	62.54	2.87	59.18	2.78	12.78*	61.71	3.20
Knee Height, Sitting	55.86	2.65	51.33	2.76	17.64*	54.74	3.31
Functional Leg Length	109.93	5.22	102.37	4.88	16.23*	108.06	6.08

* $P < 0.05$
All measures are in millimeters except weight which is kilograms.
Variables are defined in Appendix C.

Table 4. Correlation Coefficients (r) for Knee Strength and Anthropometry of Male (n=458) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.55	0.54	0.40	0.48	0.43	0.50	0.41	0.46
Thumbtip Reach	0.38	0.31	0.26	0.29	0.36	0.31	0.36	0.34
Thigh Circumference	0.38	0.42	0.28	0.38	0.27	0.39	0.24	0.36
Bideltoid Breadth	0.41	0.41	0.31	0.36	0.30	0.38	0.27	0.34
Hip Breadth	0.30	0.33	0.24	0.28	0.19	0.28	0.18	0.26
Abdominal Depth	0.21	0.27	0.13	0.23	0.15	0.25	0.14	0.23
Height	0.41	0.31	0.29	0.27	0.36	0.36	0.33	0.29
Sitting Height	0.30	0.19	0.26	0.18	0.25	0.24	0.22	0.18
Eye Height	0.28	0.16	0.26	0.15	0.22	0.21	0.19	0.16
Acromial Height	0.25	0.12	0.23	0.11	0.18	0.17	0.16	0.15
Thigh Clearance	0.42	0.47	0.29	0.41	0.34	0.47	0.31	0.41
Buttock Knee Length	0.39	0.37	0.25	0.30	0.33	0.37	0.31	0.32
Knee Height	0.44	0.37	0.29	0.32	0.37	0.38	0.36	0.32
Leg Length	0.43	0.35	0.27	0.30	0.36	0.38	0.34	0.32

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 5. Correlation Coefficients (r) for Shoulder Strength and Anthropometry of Male (n=458) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.40	0.45	0.46	0.48	0.21	0.33	0.24	0.35
Thumbtip Reach	0.18	0.21	0.25	0.29	0.12	0.16	0.14	0.17
Thigh Circumference	0.30	0.35	0.31	0.36	0.14	0.22	0.17	0.26
Bideltoid Breadth	0.36	0.42	0.40	0.44	0.21	0.32	0.25	0.37
Hip Breadth	0.19	0.25	0.24	0.29	0.05	0.12	0.10	0.17
Abdominal Depth	0.20	0.23	0.19	0.21	0.09	0.14	0.15	0.22
Height	0.10	0.10	0.25	0.22	0.04	0.15	0.02	0.09
Sitting Height	0.13	0.13	0.26	0.24	0.07	0.17	0.06	0.12
Eye Height	0.10	0.10	0.23	0.22	0.06	0.15	0.05	0.10
Acromial Height	0.11	0.10	0.21	0.20	0.04	0.10	0.05	0.07
Thigh Clearance	0.31	0.35	0.31	0.35	0.17	0.23	0.19	0.23
Buttock Knee Length	0.12	0.13	0.22	0.20	0.04	0.14	0.02	0.11
Knee Height	0.11	0.11	0.23	0.22	0.04	0.15	0.03	0.12
Leg Length	0.10	0.12	0.21	0.21	0.02	0.14	0.01	0.10

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 6. Correlation Coefficients (r) for Elbow Strength and Anthropometry of Male (n=458) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.54	0.46	0.46	0.49	0.47	0.45	0.46	0.43
Thumbtip Reach	0.31	0.23	0.19	0.24	0.24	0.25	0.24	0.24
Thigh Circumference	0.36	0.29	0.36	0.37	0.34	0.32	0.33	0.29
Bideltoid Breadth	0.46	0.41	0.40	0.42	0.42	0.40	0.43	0.38
Hip Breadth	0.27	0.25	0.27	0.29	0.22	0.22	0.23	0.23
Abdominal Depth	0.26	0.24	0.22	0.28	0.19	0.19	0.23	0.22
Height	0.30	0.24	0.17	0.17	0.22	0.23	0.19	0.21
Sitting Height	0.17	0.16	0.14	0.14	0.14	0.15	0.12	0.14
Eye Height	0.15	0.14	0.12	0.12	0.11	0.13	0.10	0.12
Acromial Height	0.12	0.14	0.10	0.13	0.08	0.08	0.08	0.10
Thigh Clearance	0.36	0.27	0.30	0.35	0.33	0.31	0.32	0.27
Buttock Knee Length	0.32	0.23	0.18	0.19	0.23	0.20	0.22	0.18
Knee Height	0.33	0.27	0.19	0.19	0.25	0.25	0.23	0.22
Leg Length	0.34	0.25	0.19	0.19	0.27	0.27	0.24	0.23

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 7. Correlation Coefficients (r) for Knee Strength and Anthropometry of Female (n=152) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.56	0.69	0.40	0.53	0.52	0.61	0.52	0.62
Thumbtip Reach	0.40	0.54	0.26	0.37	0.39	0.45	0.39	0.39
Thigh Circumference	0.45	0.52	0.32	0.45	0.41	0.49	0.41	0.49
Bideltoid Breadth	0.35	0.49	0.25	0.46	0.35	0.48	0.35	0.49
Hip Breadth	0.26	0.31	0.19	0.24	0.21	0.30	0.19	0.33
Abdominal Depth	0.33	0.40	0.27	0.32	0.27	0.34	0.29	0.38
Height	0.43	0.57	0.31	0.39	0.44	0.55	0.41	0.48
Sitting Height	0.26	0.35	0.17	0.28	0.23	0.31	0.25	0.32
Eye Height	0.27	0.36	0.16	0.27	0.23	0.31	0.24	0.32
Acromial Height	0.20	0.32	0.09	0.21	0.18	0.28	0.17	0.29
Thigh Clearance	0.38	0.54	0.23	0.44	0.41	0.48	0.41	0.46
Buttock Knee Length	0.45	0.58	0.38	0.42	0.45	0.56	0.41	0.48
Knee Height	0.34	0.55	0.25	0.39	0.41	0.52	0.37	0.42
Leg Length	0.47	0.64	0.35	0.44	0.47	0.57	0.44	0.50

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 8. Correlation Coefficients (r) for Shoulder Strength and Anthropometry of Female (n=152) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.46	0.54	0.49	0.46	0.39	0.46	0.42	0.50
Thumbtip Reach	0.24	0.24	0.32	0.27	0.32	0.41	0.22	0.34
Thigh Circumference	0.34	0.38	0.35	0.29	0.25	0.32	0.25	0.33
Bideltoid Breadth	0.39	0.40	0.41	0.33	0.28	0.25	0.34	0.35
Hip Breadth	0.14	0.25	0.18	0.18	0.10	0.17	0.13	0.20
Abdominal Depth	0.28	0.33	0.25	0.25	0.23	0.22	0.30	0.27
Height	0.28	0.30	0.37	0.32	0.33	0.40	0.26	0.33
Sitting Height	0.25	0.29	0.33	0.30	0.27	0.32	0.25	0.29
Eye Height	0.26	0.29	0.34	0.31	0.26	0.30	0.25	0.30
Acromial Height	0.19	0.19	0.22	0.18	0.16	0.15	0.16	0.14
Thigh Clearance	0.39	0.38	0.40	0.32	0.32	0.33	0.35	0.38
Buttock Knee Length	0.32	0.29	0.35	0.26	0.32	0.34	0.28	0.27
Knee Height	0.19	0.19	0.27	0.20	0.25	0.31	0.18	0.25
Leg Length	0.28	0.28	0.31	0.24	0.31	0.38	0.24	0.30

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 9. Correlation Coefficients (r) for Elbow Strength and Anthropometry of Female (n=152) Aviation Candidates.

Variables	Peak Torque		TAE		Total Work		Average Power	
	Flex	Ext	Flex	Ext	Flex	Ext	Flex	Ext
Weight	0.47	0.29	0.22	0.35	0.38	0.43	0.41	0.44
Thumbtip Reach	0.44	0.15	0.12	0.12	0.30	0.32	0.30	0.32
Thigh Circumference	0.35	0.23	0.17	0.27	0.32	0.34	0.32	0.35
Bideltoid Breadth	0.37	0.21	0.15	0.28	0.21	0.26	0.29	0.32
Hip Breadth	0.13	0.14	0.07	0.08	0.20	0.18	0.21	0.16
Abdominal Depth	0.17	0.21	0.08	0.21	0.20	0.20	0.22	0.20
Height	0.48	0.20	0.16	0.18	0.29	0.34	0.27	0.33
Sitting Height	0.33	0.23	0.15	0.25	0.21	0.22	0.23	0.24
Eye Height	0.36	0.19	0.16	0.20	0.22	0.23	0.23	0.24
Acromial Height	0.23	0.13	0.02	0.13	0.11	0.13	0.13	0.16
Thigh Clearance	0.40	0.26	0.24	0.40	0.27	0.32	0.33	0.35
Buttock Knee Length	0.41	0.19	0.08	0.18	0.21	0.34	0.18	0.33
Knee Height	0.40	0.11	0.14	0.10	0.24	0.28	0.23	0.26
Leg Length	0.45	0.19	0.13	0.14	0.30	0.38	0.26	0.34

Anthropometry variables are defined in Appendix C, strength variables in Appendix B.

Table 10. Percentage (%) comparisons of female (n=152) to male (n=458) muscular strength and endurance variables measured with the Cybex 6000 dynamometer.

Percentages (%)		Strength		Endurance	
		Peak Torque	TAE	Total Work	Ave Power
Knee	Flexion	64	63	65	67
	Extension	66	60	63	64
Elbow	Flexion	56	45	45	43
	Extension	65	58	55	56
Shoulder	Flexion	61	56	56	57
	Extension	60	58	58	62

MEETING ABSTRACTS

Pokorski, T.L., Meyer, L.G., Ortel, B.E., Saxton, J.L., and Collyer, P.D. Muscular strength characteristics of male and female naval aviation candidates. Aerospace Medical Association Annual Meeting, p. A22, May 1996.

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